

EVALUATION ON OMNISTAR WIDE AREA DGPS SERVICE¹

**Mustafa Din Subari, Mohamad Saupi Che Awang, Hamsah Supian
and Saiful Sukri Suarni**

Satellite Navigation Research Group (SNAG)
Department of Geomatic Engineering
Faculty of Geoinformation Science and Engineering
Universiti Teknologi Malaysia
E-mail: m.subari@fksg.utm.my

Abstract

OmniSTAR is a wide Area Differential Global Positioning System (WADGPS). The system transmits differential GPS correction data world wide using a global network of reference stations (90 stations) to measure the errors induced into the GPS signal. This reference data is gathered at a network control center (NCC) (at Houston, Texas and Perth, Australia) where it is checked for integrity and reliability and it's up-linked to a series of geo-stationary satellites, which distribute the data to the users worldwide.

This paper describes project undertaken at the SNAG research Group at the Universiti Teknologi Malaysia. The study was conducted to specifically evaluate the performance of commercial WADGPS services that are assessable and available in Malaysia. OmniSTAR Performance Test has done for a of 28 days duration in May 2003 at UTM, Johor Bahru using Omnilite 132 DGPS Receiver. Initial results shows that while several days, service availability was 100%, there are days when service availability was only 90%. Horizontal accuracy was found to be consistently good to a meter while height accuracy was slightly worst.

1.0 INTRODUCTION

The core GNSS services, either GPS or GLONASS basic-service alone may not meet the requirement of *Integrity*, *Accuracy*, *Availability* and *Continuity* requirement of certain navigation users. *Integrity* is the ability of a system to provide timely warnings to users when the system should not be used for navigation. *Accuracy* is the difference between the GPS-measured position at any given time and the actual or true position. *Availability* is the coverage of the system in time and space – whether sufficient satellites are visible to allow accurate positioning when and where the users need it. *Continuity* is the probability that the service will perform its function within defined performance limits for a period of time given (Ochieng and Sauer, 2002). Augmentation systems, or sometimes known as Differential GNSS (DGNSS), has been setup to achieved those *service reliability* to a certain level.

Augmentation systems have been setup by many organizations, government as well as private. To enhance service reliability, these systems broadcasted GPS-like ranging signal, as well as other information so users can know their position with higher assurance.

A project was undertaken at the SNAG research Group at the Universiti Teknologi Malaysia to study on the performance of augmentation services available in Malaysia. This paper reported results of study on the OmniSTAR Differential GPS service; in particular, the attainable service *availability* and *accuracy*.

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2.0 GNSS AUGMENTATION SERVICES

A GNSS receiver calculates its position by determining its distance from the many GNSS satellites that orbit the earth. A good receiver using both the L1 and L2 signals can determine its position to within 2 meters. The receiver can determine its position more accurately if it has access to differential GNSS (DGNSS) corrections. A reference GNSS receiver is placed at a known location, and the difference between the location it gets from the satellites and the true location is calculated. This difference is then transmitted to the user's receiver, which adjusts its position calculations to compensate for the error that the reference receiver found. For single-reference difference GNSS (DGNSS), range errors are calculated for each satellite observed at a single reference station and transmitted to remote users. Under normal conditions, the errors remaining after differential processing are due to atmospheric effects (both tropospheric and ionospheric errors), multipath and to a lesser extent, orbital errors. Corrections for spatially correlated errors (atmospheric and orbital effects) become less effective with increased baseline length, and DGPS positioning accuracies can be significantly degraded over longer baselines. Limitations therefore exist in both availability and positioning accuracy when employing the single-reference DGNSS approach.

Wide Area DGNSS

With growing demand of accurate and reliable GNSS positioning worldwide, wide area differential GNSS (WADGNSS) services have been developed in recent years. In a WADGNSS system, a network of reference receivers combines to create a model of the best DGNSS correction for a wide area. In this system wide area approach, GNSS observations from a sparse network of reference stations are used to model correlated errors sources over an extended region. Such WADGNSS services allow consistent levels of positioning accuracy to be achieved at all locations within the coverage area. There are several different approaches and algorithms that may be used to derive WADGNSS corrections. There are three approaches (Abousalem, 1996) to solving the Wide Area Differential GNSS problem: 1) the measurement domain approach, 2) the position-domain approach, and 3) the state-space approach. The measurement and position domain algorithms effectively solve the problem by performing a weighted mean of the individual DGNSS sites. The mean is taken either across the correctors themselves (measurement domain), or on the GPS position solutions resulting from using the individual DGNSS sites (position domain). The state-space approach solves the problem more elegantly by computing the actual physical quantities comprising the pseudorange error. Geostationary satellites then broadcast this correction in the same band that regular GPS satellites use. The result is a DGNSS correction that can be deciphered by any WADGNSS-enabled receiver.

3.0 OmniSTAR, WideArea DGPS Service

OmniSTAR is a wide Area Differential Global Positioning System (WADGPS) that provides correction data to subscribers of the system with the use of geostationary transponders. The system transmits differential GPS correction data world wide using a global network of reference stations (90 stations) to measure the errors induced into the GPS signal. This reference data is gathered at a network control center (NCC) (at Houston, Texas and Perth, Australia) where it is checked for integrity and reliability and it's up-linked to a series of geo-stationary satellites, which distribute the data to the users worldwide. The corrections from all reference stations are checked at the NCC, and then they are compressed and formed into packets for upload to the

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OmniSTAR satellite transponders. This occurs approximately every 2.5 seconds. A packet contains the latest corrections from each of the reference stations.

The OmniSTAR system is comprised of three main components; the Reference Stations, the Network Control Center and the User. Figure 1 shows the components of OmniSTAR system. Each reference station consists of a dual frequency narrow correlator GPS receiver and a connection to the Network Control Center (NCC). These stations track all GPS satellites above 5 degrees and compute corrections every 600ms. The corrections are then sent to the NCC in RTCM-104 Version 2.0 format.

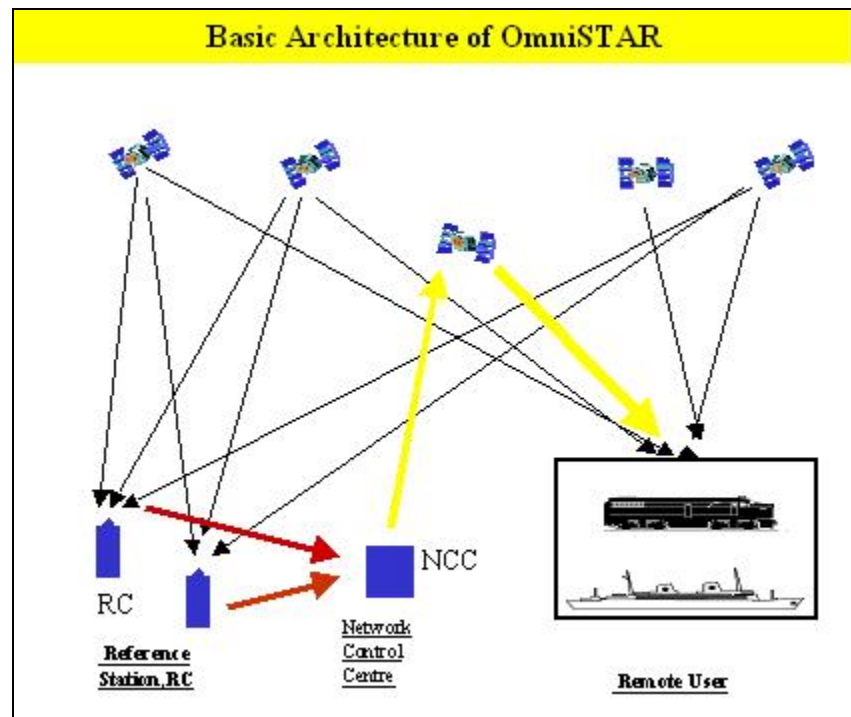


Figure 1: OmniSTAR Differential GPS Service

The OmniSTAR user set receives packets of data, which are first decoded and uncompressed. Using Virtual Base Station (VBS) processing algorithms, the software interpolates corrections, specific to user location. To ensure a consistent level of accuracy across the entire coverage area, the resulting RTCM corrections are those that would be calculated if a reference station were set up at the user's present location.

Therefore each OmniSTAR user set must be given an approximate location within several kilometers of its true position. An OmniSTAR user set is normally purchased as an integrated GPS/DGPS system, and the position output of the GPS receiver is used as the approximate location.

The OmniSTAR service uses geostationary satellites for communication; the elevation angle to these satellites is dependent upon latitude. Obstructions such as trees, buildings, terrain, or other objects for latitudes higher than approximately 55° north and south may block the OmniSTAR signal more easily. This will lead to a longer correction age in these areas. With SA

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turned off corrections change very slowly and correction will be valid for several minutes. In normal condition, the age of corrections ranges from 3 to 5 seconds, and the correction age ranges from 3 to 9 seconds if there is no signal.

4.0 THE TEST

The experiment was conducted at UTM, Johor Bahru from May 3rd, 2003 to May 26th, 2003. The receiver used in this experiment is Omnilite 132 DGPS Receiver from OmniSTAR. The antenna of the Omnilite was setup on a platform on top of the four-story building, with a 15-meter cable connecting it to the Omnilite receiver in the SNAG lab.

The Omnilite 132 is a differential correction receiver with 12 parallel channel which tracks up to 12 satellites, using L1 GPS L-band signal and 1 Hz standard update rate. Data input and output using RS232 serial ports with optional data rates of 4800, 9600, 19200, 38400 bps.

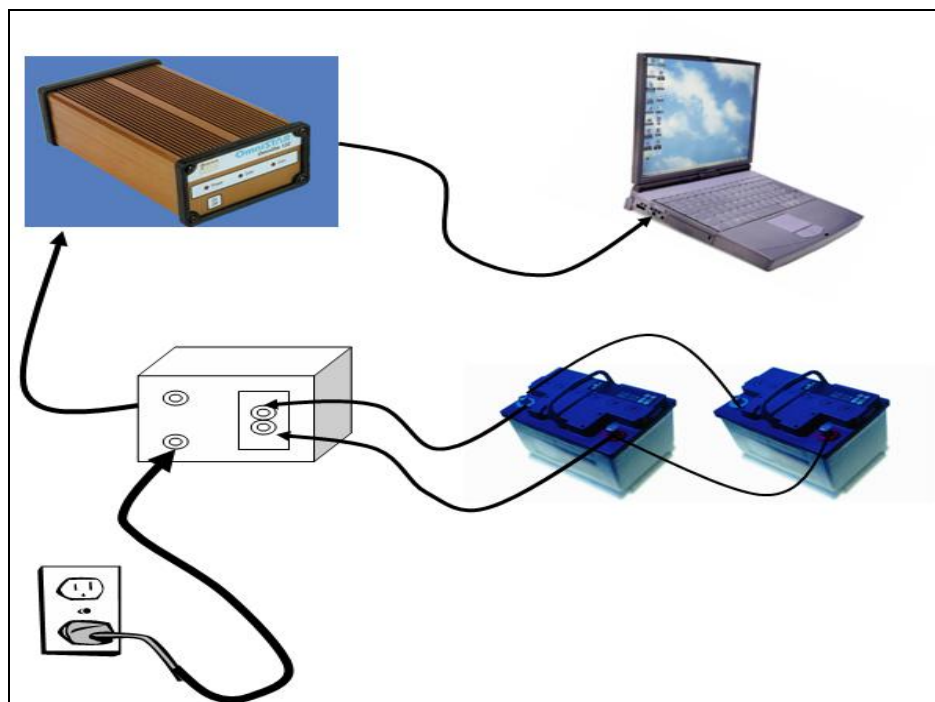


Figure 2: Equipment setup and power supply.

The receiver data logger memory was not enough to save the data collection for this continuous observation campaign, therefore, a computer is connected to the RS232 port terminal at the receiver and data collected via hyper terminal. The collected data were in NMEA format. To ensure no power interruption during observation, a battery back up and a unit of dc power supply are connected in a parallel setup. Figure 2 shows the equipment setup of the experiment.

Data post processing was performed using in-house software developed by SNAG group. The continuous data the software divided the data on daily basis. Another software used get data required from the NMEA message (HDOP, number of satellites, position, time, etc).

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5.0 RESULTS AND ANALYSIS

Continuous observations were carried out from May 3rd, 2003 to May 26th, 2003 (26 days) on 1-second data rate. Some technical problems occurred on the day 15 and day 16, hence data from those days were incomplete. A simple program was written to divide the two large data files into daily data files (UTC 0 hours to 24 hours). The program also extract out the required data from the NMEA format. Daily observation data files were then inspected.

Service Availability. From the data analysis, it was found that from the 26 days of campaign, 22 days recorded full 86,400 data fixes (1 second fixes for 24 hours) (days 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 17, 18, 19, 20, 21, 22, 23, 24 and 25), while the other four days (day 1, 15, 16 and 26) has less number of fixes (Table 1). From the 22 full data fixes days, two days has recorded some invalid fixes, day 3 with 427 invalid fixes and day 18 with 64 invalid fixes respectively. Reasons for this invalid fixes are unknown. Then several days were found to have GPS alone fixes, i.e. no differential corrections were received, these are day 3 with 53 fixes and day 5 with 129 fixes respectively. From these results, data outliers are further inspected. Fixes with greater than 3 RMS are identified as in error. For this analysis, day 3, 6, 9, 13, 14, 19, 20, 21, and 24 are identified to have outliers as indicated in table 1. Service availability was computed for each day as a ratio of good fixes over the total fixes. This give 11 days with full 100% availability, with other days ranging from 99.9954% to lowest of 99.4144% availability for day 3.

Accuracy: The obtained fixes (latitude, longitude and heights) are compared to the mean values computed for the whole period of the campaign. Figure 9 shows plot of the standard deviation of each coordinate components. The standard deviation of the latitude and longitude is less than 0.5 meters, while the height were below 1 meter. Several spikes in the plots were due to the outliers in the data, which was not removed. These are on days, 3, 6, 9, 12, 13, 14, 19, 20, 21, and 24, where their values ranges from 3 up to 45 m.

Other aspects on the data were also analyzed. Correction ages or latency of the differential corrections was found within 3 to 11 seconds. Fixes identified as outliers were detected where latency values are found as large as 20 seconds.

The number satellites available vary throughout the observation days. Generally, the highest number (from 9 to 11 SVs) was found during UTC 6 hr to 12 hr (Malaysian Time: 2 pm to 6 pm), and the smallest number down to just 5 satellites. Most of the time, 8 satellites were available. On the other hand HDOP values were recorded to be within 1 to 2 throughout the observation.

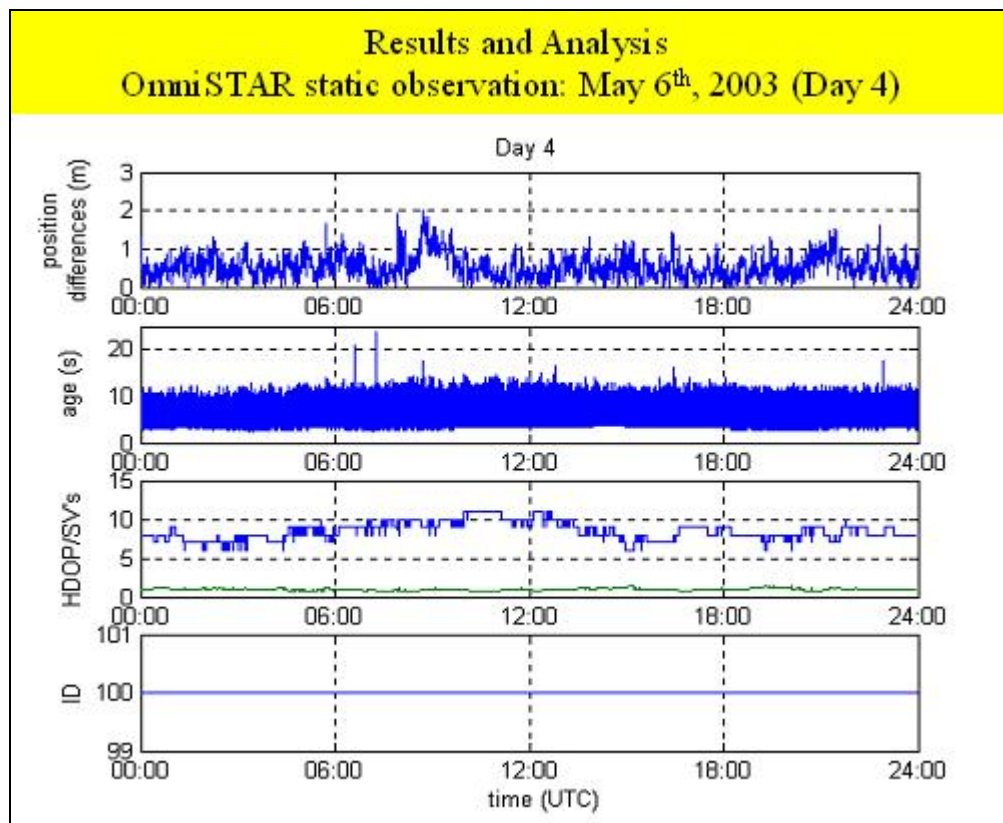
The following figures show results from day 4 and day 3. Day 4 is considered as good observation day with 100 % service availability, while day 3 is the worse day with only 99.4144%. The figure shows position difference (vector difference, $\sqrt{dlat^2 + dlong^2}$), the age of the differential correction and the HDOP. The ID #100 shows that the correction is indeed from OmniSTAR. Day 4 recorded position differences of between 1-2 meters, with height slightly worse of up to 3 meters. Day 3 recorded outliers in the early observation data, with magnitude up to 40 over meters for position and 60 over meters for height, while the rest of the fixes are as good as day 4.

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OmniSTAR static test: Outlier and Availability

Day	Total fix	Not valid fix	Recorded fix	GPS alone fix	OmniSTAR fix	OmniSTAR fix with outlier	OmniSTAR availability (%)
1	72,223	0	72,223	0	72,223	0	100.0000
2	86,400	0	86,400	0	86,400	0	100.0000
3	86,400	427	85,973	53	85,920	26	99.4144
4	86,400	0	86,400	0	86,400	0	100.0000
5	86,400	0	86,400	129	86,271	0	99.8507
6	86,400	0	86,400	0	86,400	4	99.9954
7	86,400	0	86,400	0	86,400	0	100.0000
8	86,400	0	86,400	0	86,400	0	100.0000
9	86,400	0	86,400	0	86,400	118	99.8634
10	86,400	0	86,400	0	86,400	0	100.0000
11	86,400	0	86,400	0	86,400	0	100.0000
12	86,400	0	86,400	0	86,400	0	100.0000
13	86,400	0	86,400	0	86,400	25	99.9711
14	86,400	0	86,400	0	86,400	5	99.9942
15	14,860	0	14,860	0	14,860	18	99.8789
16	71,490	0	71,490	0	71,490	0	100.0000
17	86,400	0	86,400	0	86,400	0	100.0000
18	86,400	64	86,336	0	86,336	0	99.9259
19	86,400	0	86,400	0	86,400	21	99.9757
20	86,400	0	86,400	0	86,400	38	99.9560
21	86,400	0	86,400	0	86,400	5	99.9942
22	86,400	0	86,400	0	86,400	0	100.0000
23	86,400	0	86,400	0	86,400	0	100.0000
24	86,400	0	86,400	0	86,400	137	99.8414
25	86,400	0	86,400	0	86,400	0	100.0000
26	11,595	0	11,595	0	11,595	0	100.0000

Table 1: Availability of OmniSTAR test.



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Figure 3: Results of Day 4.

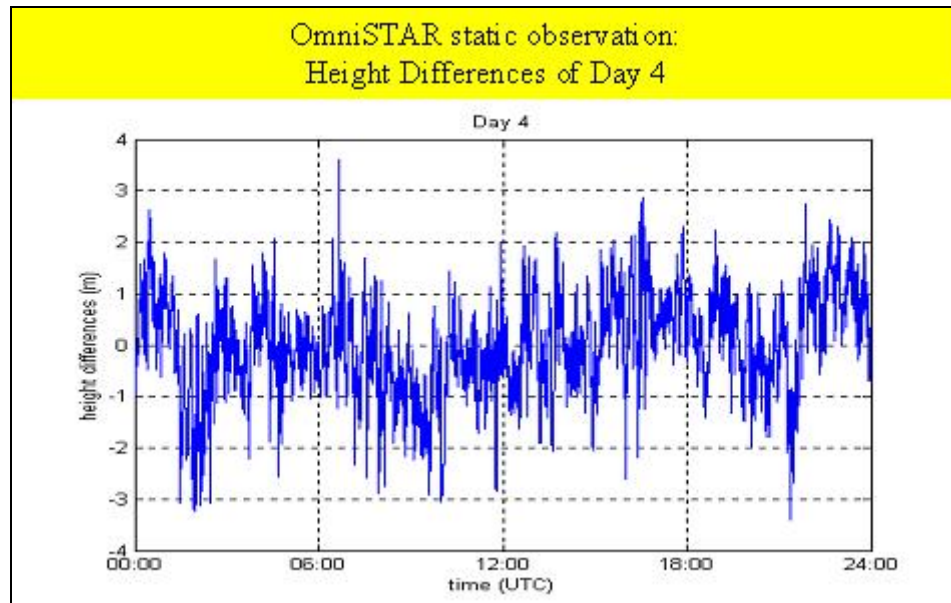


Figure 4: Height Differences of Day 4

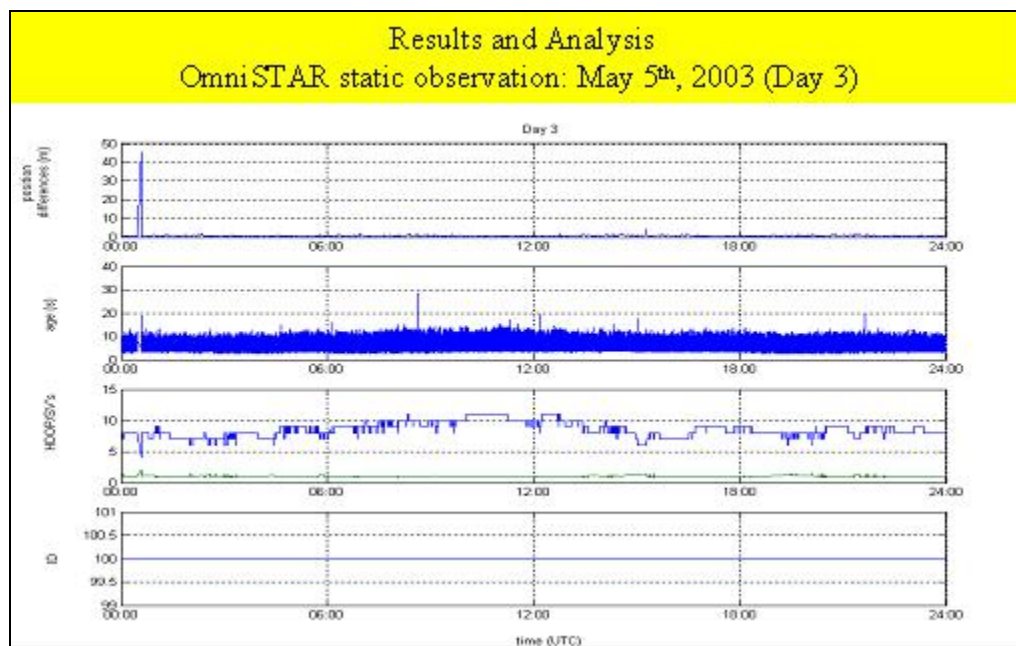


Figure 5: Results of Day 3.

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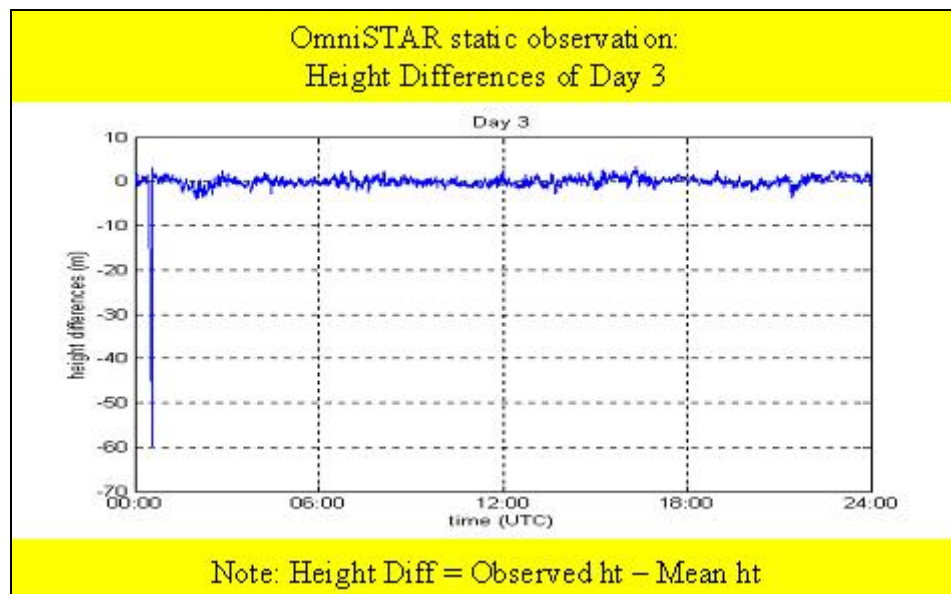


Figure 6: Height Differences of Day 3.

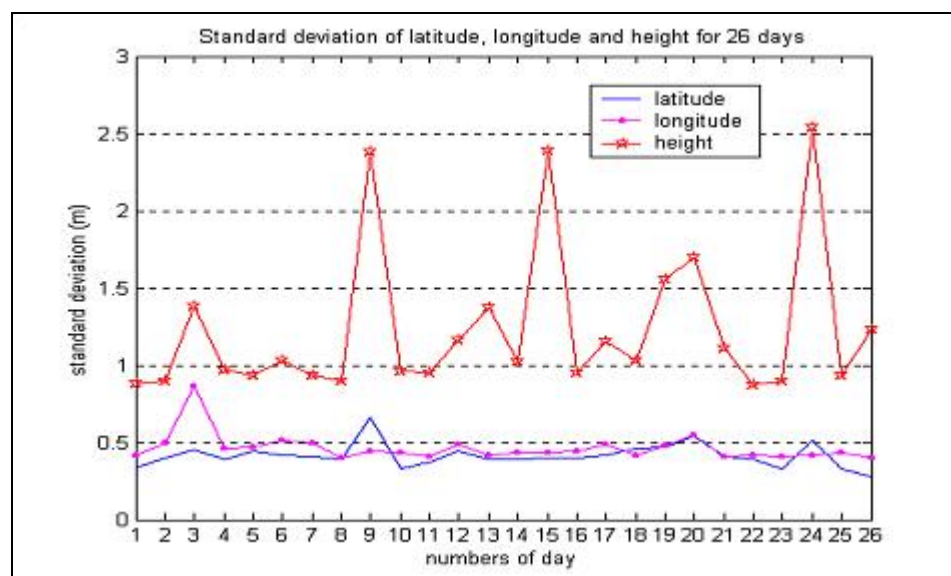


Figure 7: Summary of Position Accuracy.

6.0 CONCLUSIONS

The paper reported an evaluation on the OmniSTAR performance in Malaysia. The OmniSTAR system provides a commercial service using a series of ground reference station worldwide. Field test was carried out in UTM, Skudai whereby 24 hours of data was collected using Omnilite 132 receiver. The observation campaign was carried out for a period of 26 days.

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The results were analyzed by looking at the service availability and positioning accuracy of the system. On the service availability, out of 22 days of observation, 11 days gave full 100% availability, with other days giving service availability ranging from 99.9954% to lowest 99.4144%. Positioning (latitude and longitude) accuracy was found to be between 1-2 meters with standard deviation of than 0.5 meters, while the height were between 1-3 meters with standard deviation below 1 meter.

ACKNOWLEDGEMENT

Several agencies and individuals are greatly appreciated for their help and contribution in this test, namely our organization, the Universiti Teknologi Malaysia, and The National Space Agency, Malaysia, for providing the funding, and lastly, to our SNAG members Rozaimi, Aidil, Adi and others whom has assisted in the observation and processing of data. Thank you all.

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